Advanced Graphics
(simulation-based methodology)

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What is Simulation?

Simulation

Article Talk

From Wikipedia, the free encyclopedia

For other uses, see Simulation (disambiguation).
Not to be confused with Stimulation or Emulation (computing).
"Simulator" redirects here. For other uses, see Simulator (disambiguation).

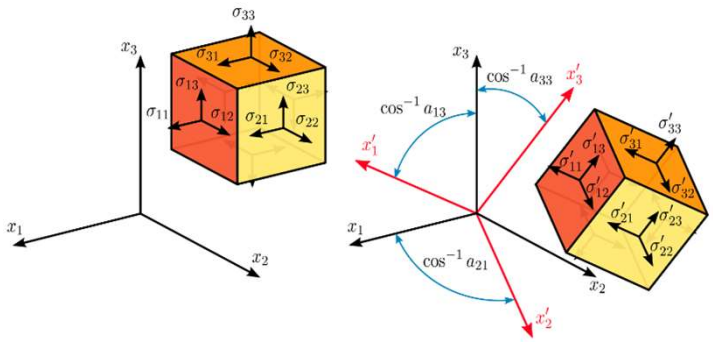
A **simulation** is the imitation of the operation of a real-world process or system over time.[1] Simulations require the use of models; the model represents the key characteristics or behaviors of the selected system or process, whereas the simulation represents the evolution of the model over time. Often, computers are used to execute the simulation.

Sources :
(a) https://en.wikipedia.org/wiki/Simulation

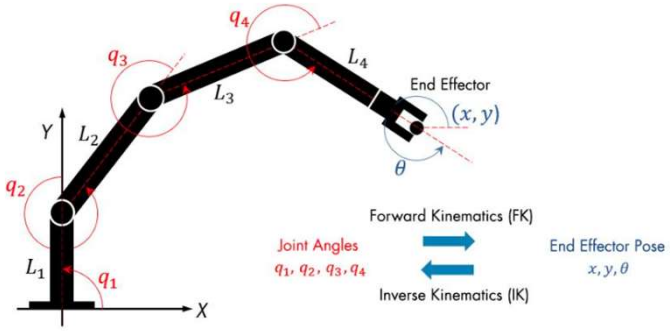
Syllabus

https://glittery-capri-4d8.notion.site/2023-Spring-Advanced-Graphics-Physics-based-Methodology-df47ada629da4dad8ac7c516f08f09e2

Basics



Transformations

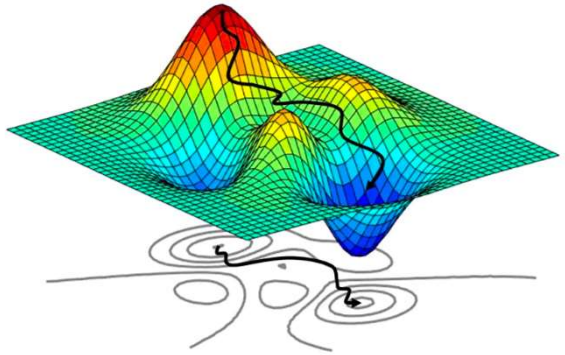


Kinematics

$$\begin{bmatrix} 1 & 3 & 1 \\ 2 & 2 & 2 \\ 3 & 1 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 5 \\ 6 \\ 5 \end{bmatrix}$$

A x b

Solving Linear System



Optimization

Crowd Simulation

- Modeling the behavior (or dynamics) of a large number of entities (e.g. humans, birds, fishes, robots, etc.)

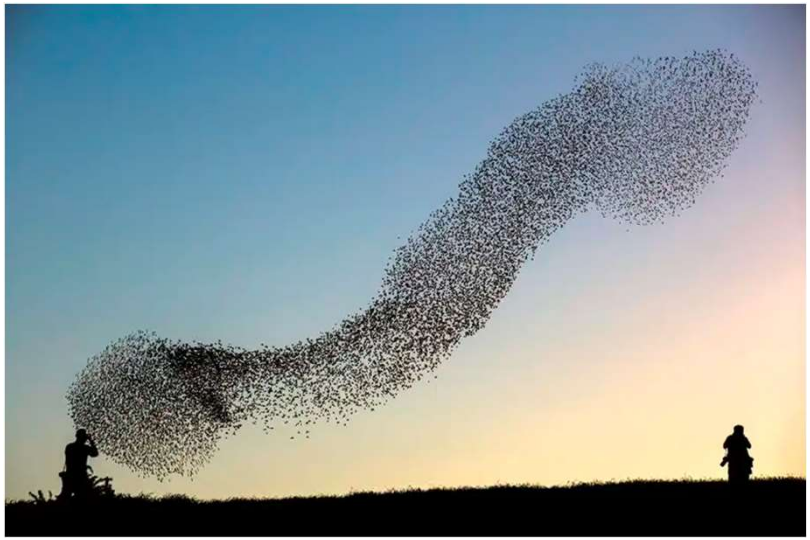


Image sources :
(a) Dynamic Deformables:Implementation and Production Practicalities (SIGGRAPH 2022 Course)
(b) Amir Cohen/Reuters - https://www.newscientist.com/article/dn27643-wave-motion-shows-how-bird-flocks-have-to-be-just-the-right-size/

Crowd Simulation

Soft-body (Deformable) Simulation

- Modeling the behavior of deformable objects (e.g., human skin, soft-bodied animals, and clothes)

Image sources :
(a, b) Dynamic Deformables:Implementation and Production Practicalities (SIGGRAPH 2022 Course)
(c) Dynamic Deformables:Implementation and Production Practicalities (SIGGRAPH 2022 Course)

Soft-body (Deformable) Simulation

Rigid-body Simulation

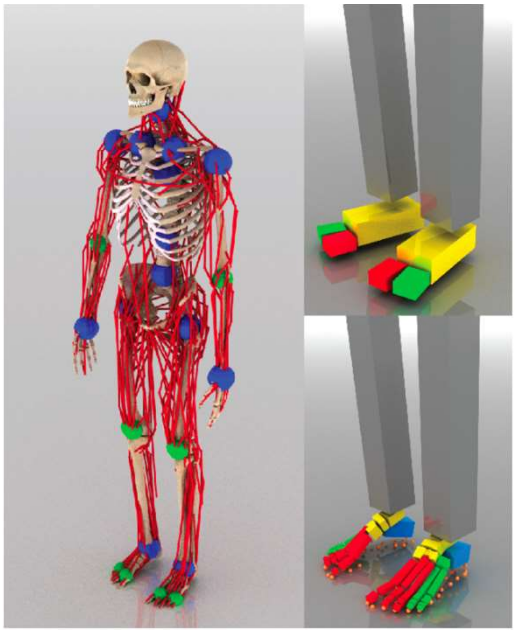


Image sources :
(a) Getty
(b) Lee et al. Scalable Muscle-actuated Human Simulation and Control, SIGGRAPH 2019
(c) Boston Dynamics

Rigid-body Simulation

Terrain and Ecosystem Simulation

- Realistic terrains and plants can be generated via simulating how they were created in nature

Image sources :
(a) https://nextnav.com/hat/
(b) https://outforia.com/types-of-terrain/
(c) https://www.gardeningknowhow.com/ornamental/trees/tgen/hardwood-tree-information.htm

Terrain and Ecosystem Simulation

Fluid Simulation

- Modeling the behavior of fluids (e.g. water, honey, fire, smoke)

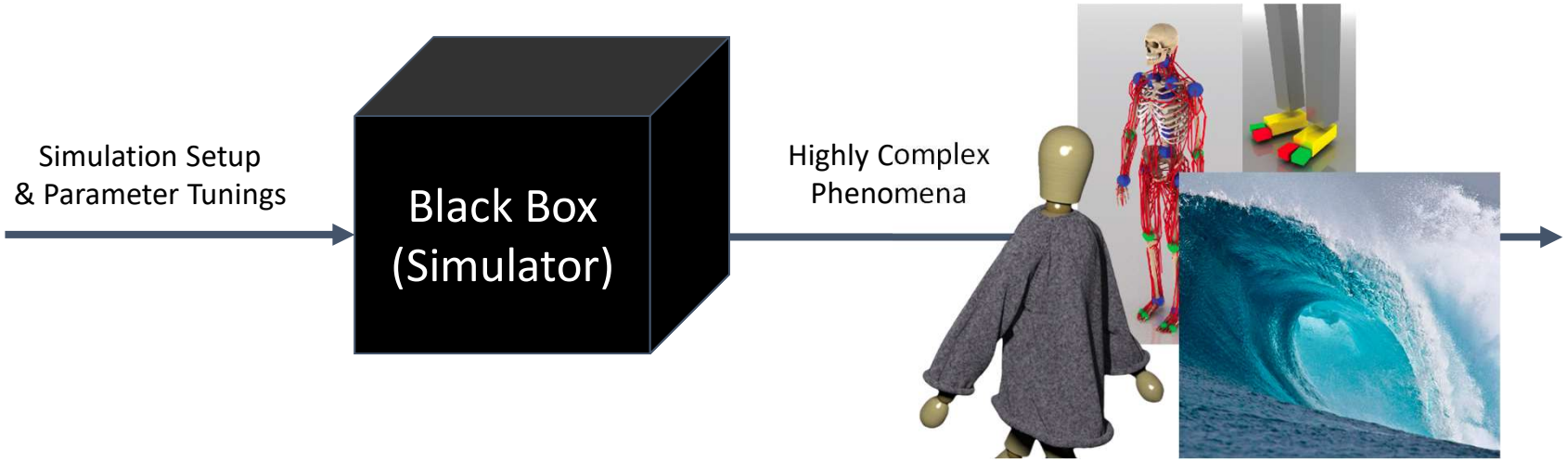
Image sources :
(a) https://en.wikipedia.org/wiki/Breaking_wave
(b) https://www.jessicagavin.com/honey-benefits/
(c) AP Photo/Rich Pedroncelli

Fluid Simulation

- Web demo
  - https://madebyevan.com/webgl-water/

Control of Dynamic System

- We usually treat the simulator as a black box



- This process is well-suited when such behaviors are auxiliary effects in the desired applications
  - you don’t care about all the details in results as long as they look great

Control of Dynamic System

- Control of dynamic system means that finding appropriate simulation setup and control parameters so that the simulated scene appears as we want

- Examples
  - You want the waves or clothes moving in a certain way while making movies
  - You want to develop a robot controller so that the robot follows your instruction
  - You want to design a car or an air plane so that their shapes are more energy efficient (e.g., lower air resistance)

Summary

- In this course, we will get a taste of the topics below
  - Basic math for simulation-based computer graphics
  - Crowd simulation
  - Soft and rigid body simulation
  - Terrain and ecosystem simulation
  - Fluid simulation
  - Control of simulated system

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